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Engineering and Design
STABILITY CRITERIA FOR EXISTING CONCRETE
NAVIGATION STRUCTURES ON ROCK FOUNDATIONS

1. Purpose. The purpose of this letter is to provide interim criteria and procedures for analyzing and for improving the stability of existing concrete navigation structures on rock foundations. Concrete navigation structures include lock walls, lock chambers, and approach walls.

2. Applicability. This letter is applicable to all field operating activities having responsibilities for the design and construction of civil works projects.

3. References. See Enclosure 3.

4. Background. Past practice has been to use the same stability criteria for designing new structures and for reviewing existing structures. Most of the existing structures, although not meeting the referenced stability criteria (ref. 5, 6, 7 & 8), have performed satisfactorily for many years. It may not be necessary to improve the structure's stability to satisfy the referenced criteria when the remaining life of the structure is relatively short or when there are no indications of any stability problem. Relaxation to the referenced criteria have been granted on a case by case basis. A research investigation, as a part of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Program (ref. 9), was undertaken to study the stability of the existing concrete structures. The preliminary results of the REMR research and the experience from recent rehabilitation projects are included in this ETL. Revisions will be made as the additional results from REMR research and other sources become available.

5. Procedures. The following procedures shall be used in the evaluation of current stability conditions and in the determination of necessary corrective measures. They should be considered as guides and are not intended to replace engineering judgement by the engineers responsible for the project. The stability condition should be reviewed when there are significant changes in the loading conditions, severe damage due to accident,

aging or deterioration, discovery of structural deficiencies, revision of stability criteria to become more conservative, or when required by ER 1110-2-100 (Ref. 2). The phases listed below shall be followed in sequence until the prescribed conditions are satisfied. The procedures are illustrated with a flow chart in Enclosure 1.

a. PHASE I, Preliminary Analyses and Evaluation. Preliminary analyses should be performed based upon available data and actual conditions of the structure. Before performing the analysis, collect and review all the available data and information for the structure including geologic and foundation data, design plans, as-built plans, periodic inspection reports, damage reports, repair and maintenance records, plans of previous modifications to the structure, measurements of movement, instrumentation data, and other pertinent information. It may be necessary for the engineer to inspect and examine the existing structure to assess its condition. Friction between the backfill and wall or on a plane within the backfill may be considered in the stability analyses of existing structures. Recent REMR research indicated that neglecting wall friction or shear force in the backfill is unnecessarily conservative (ref.9). Preliminary results indicates that no more than 50% of the shear force maybe considered effective in resisting overturning and sliding. Calculation of shear force on the assumed shear plane maybe found in most soil mechanics text books such as in Chapter 10, ref. 13. If the results of the analyses indicate that the structure satisfies the referenced stability criteria, no further investigation is needed. Otherwise, list all the possible remedial schemes and prepare the preliminary cost estimate for each scheme. ER 1130-2-417 (ref. 4) should be followed if applicable.

b. PHASE II, Study, Investigation, and Comprehensive Analyses. When the preliminary analyses indicate that the structure does not meet the referenced criteria, a meeting should be arranged to decide on plans for the proposed comprehensive analyses, and to define the extent of the sampling and testing program, the remedial schemes to be studied, the extent of the parametric study, and the proposed schedule. This meeting should include representatives from the district, division, CEEC-E, and CECW-O. The meeting will facilitate the design effort and should obviate the need for major revisions or additional studies when the results are submitted for review and approval. The parametric study should be performed to determine the effect of each parameter on the structural stability. The parameters to be studied should include, but not be limited to, unit weight of concrete, ground water levels, uplift pressures, and shear strength parameters of the backfill material, rock or soil

foundation, and structure-foundation interface. The maximum variation of each parameter should be considered in determining its effect. An exploration, sampling, testing, and instrumentation program should be developed, if needed, to determine the magnitude and the reasonable range of variation for the parameters which have significant effects on the stability of the structure as determined by the parametric study. The division laboratory should be used to the maximum extent practicable to perform the testing in accordance with ER 1110-1-8100 (ref. 1). Comprehensive stability analyses should be performed using the material properties obtained from the sampling and testing program and procedures from referenced guidances plus the use of shear friction as discussed in paragraph 5.a. Lateral earth pressure may be reduced to the active state except when very loose or expansive material was used for the backfill. Preliminary results from REMR research indicate that the lateral earth pressure can be greatly reduced from the at-rest pressure with very small wall movement ratio (ref. 9). Since the wall must translate and/or rotate prior to failure, an active condition is justified in the analyses for structures with dense and stiff backfill. Smaller reduction should be used for other types of backfill (p.380, ref. 10). The amount of reduction of lateral earth pressure should be determined after careful evaluation of data from field investigations and material testing. Three dimensional modeling should be performed to achieve a more accurate prediction of the structural behavior when required (ref. 12). No remedial measures are required if the referenced criteria are satisfied.

c. PHASE III, Deviation from Referenced Criteria. If the structure still cannot meet the referenced criteria, deviation may be considered. Since the purpose of incorporating a factor of safety in structural design is to provide a reserved capacity with repect to failure, a lower factor of safety may be justified in the analysis of existing structures if a higher degree of confidence in the values of the critical parameters can be achieved from the field investigation. Table 1 lists the minimum stability criteria for the analysis of existing structures. If analysis indicates safety factors are above the values listed in Table 1, the stability of the structure may be acceptable without remedial measures. The request for deviation from the referenced criteria shall be submitted to CEEC-E for approval with the following documentation:

(1) Comprehensive stability analyses and cost estimates for all schemes of remedial measures.

(2) Past performace of the structure, inculding instrumentation data and description of the structure condition such as cracking, spalling, displacements, etc.

(3) The anticipated remaining life of the structure.
(4) A description of consequences in case of failure.

TABLE 1
MINIMUM STABILITY CRITERIA FOR
EXISTING NAVIGATION STRUCTURES

CASES	NORMAL COND.	MAINT. COND.	SEISMIC COND.
% COMP. AREA/ BASE AREA	75%	50%	RESULTANT WITHIN BASE
F.S.--SLIDING	1.60	1.25	1.10

NOTE: Maximum base pressure shall not exceed the allowable unit bearing capacity of the foundation material in all cases.

6. Stability Requirements For Remedial Measure. The reduction of lateral pressure and introduction of shear friction as listed in paragraph 5.a and 5.b and the relaxation of design criteria in Table 1 shall not be used in the design of remedial measures such as prestressed and non-prestressed anchors. The remedial measure shall be designed to meet the referenced stability criteria. In unusual cases where this is not practical, the allowed minimum stability criteria shall be determined at a meeting with the district, division, CEEC-E, and CECW-O. Construction plans, specifications, and cost estimate for the proposed remedial measures should be developed in accordance with ER 1110-2-1200 (ref. 3).

7. Prestressed Anchors. Prestressed anchors may be used to stabilize the existing walls, foundation slabs, and concrete monoliths. They are effective in improving the safety factors against overturning, sliding, and uplift. The number, orientation, and capacity of anchors used should be based on engineering considerations and stability requirements. The existing concrete and structure should be checked for its adequacy to withstand the sustained load at the anchorage points. Anchors installed in aggressive environments should be provided with double corrosion protection. Design, installation, and testing of anchors and anchorages should be in accordance with reference 11. Allowable bond stress used to determine the length of embedment between grout and rock should not be more than 50 percent of the ultimate bond stress determined by tests. The

values of bond strength in paragraph 4.3.2.6 of reference 11 may be used in lieu of tests during the design, but the design value should be verified by tests before or during construction. In addition to the first three anchors, a minimum of five percent of the anchors, but not less than two anchors, selected by the engineer, shall be performance tested.

8. Non-prestressed Anchors. Non-prestressed anchors shall not be used if other options are feasible. The effectiveness of this system is questionable and undependable due to the movement required to activate the anchor force. Therefore, the system should not be considered as effective in improving the safety factor for the structure's stability. They may be used as the last resort to prevent any possibility of catastrophic failure. The location, design, and installation of the anchors may follow the guidance provided in Enclosure 2. Bond strength used in calculating embedment length shall be verified by pull out tests in the field or laboratory.

FOR THE COMMANDER:

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